BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE (BITS) PILANI – Pilani Campus
Comprehensive Exam |OPEN BOOK| Date: 09.12.2023| Time: 180 min. | Total Marks: 120
First Semester, 2023 – '24 | CHE F213 | Chemical Engineering Thermodynamics

ID | **Name** | **Section** |

1.

An electric motor under steady load draws 9.7 amperes at 110 volts; it delivers 1.25(hp) of mechanical energy. The temperature of the surroundings is 300 K. What is the total rate of entropy generation in $W \cdot K^{-1}$?

[15 Marks]

2.

Calculate Z and V for sulfur hexafluoride at 75°C and 15 bar by the following equations:

(*a*) The truncated virial equation with the following experimental values of virial coefficients:

$$B = -194 \text{ cm}^3 \cdot \text{mol}^{-1} \quad C = 15{,}300 \text{ cm}^6 \cdot \text{mol}^{-2}$$

(*b*) The truncated virial equation with a value of B from the generalized Pitzer correlation
(*c*) The Redlich/Kwong equation
(*d*) The Soave/Redlich/Kwong equation
(*e*) The Peng/Robinson equation

For sulfur hexafluoride, $T_c = 318.7$ K, $P_c = 37.6$ bar, $V_c = 198 \text{ cm}^3 \cdot \text{mol}^{-1}$, and $\omega = 0.286$.

[25 Marks]

3.

A system formed initially of 2 mol CO_2, 5 mol H_2, and 1 mol CO undergoes the reactions:

$$CO_2(g) + 3H_2(g) \rightarrow CH_3OH(g) + H_2O(g)$$
$$CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O(g)$$

Develop expressions for the mole fractions of the reacting species as functions of the reaction coordinates for the two reactions.

[10 Marks]

PTO

4. In order to prepare 2 m^3 of alcohol-water solution, alcohol of mole fraction 0.4 is required to be mixed with water at 25°C. Determine the volume of alcohol and water needed to prepare the mixture. Given that,

Partial molar volume of alcohol = 38.8 x 10^{-6} m^3/mol

Partial molar volume of water = 17.2 x 10^{-6} m^3/mol

Molar volume of alcohol = 39.21 x 10^{-6} m^3/mol

Molar volume of water = 18 x 10^{-6} m^3/mol **[10 Marks]**

5. Assuming the validity of Raoult's law, do the following calculations for the benzene(1)/toluene(2) system:

(*a*) Given $x_1 = 0.33$ and $T = 100°C$, find y_1 and P.
(*b*) Given $y_1 = 0.33$ and $T = 100°C$, find x_1 and P.
(*c*) Given $x_1 = 0.33$ and $P = 120$ kPa, find y_1 and T.
(*d*) Given $y_1 = 0.33$ and $P = 120$ kPa, find x_1 and T.

[20 Marks]

6. Using the virial equation of state estimate the residual enthalpy and entropy for propane at 60°C and 2.5 bar. **[10 Marks]**

7. Exhaust steam at 100 kPa and 200°C enters the subsonic diffusion of a jet engine steadily with a velocity of 190 m/s. The inlet area of the diffuser is 2000 cm^2. The steam leaves the diffuser with velocity of 70 m/s. The pressure difference increase is 200 kPa. The heat losses from the diffuser to the surrounding is estimated to be 100 kW. Determine,

a) The mass flow rate of the steam.
b) The temperature of the steam leaving the diffuser.
c) The area of the diffuser outlet.

Given that, V_1 = 2.172 m^3/kg and H_1 = 2875.3 kJ/kg **[15 Marks]**

8. Estimate the fugacity of iso-butane at 15 atm and 87 °C using the compressibility factor correlation, given that the second virial coefficient, B is -4.28 x 10^{-4} m^3/mol. **[15 Marks]**

End